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Ambient Lighting's Impact on PACS Softcopy Viewing

The softcopy image you see on the CRT screen is the sum of reflected ambient light from the room added to the intended image. How one deals with this is important. Vital information can be lost to the eye if the display luminance of the image data on the screen is below the prevailing ambient luminance. In planning a PACS installation, careful attention should be given to the characteristics of the display devices to be used in relation to the ambient lighting.

Ambient Light Levels

The light level in a room is described by the amount of light that strikes particular surfaces of interest, ambient illuminance (Lux). Conditions vary throughout the hospital environment from below 10 Lux in diagnostic reading rooms (x-ray) to over 300 Lux in emergency trauma and surgical rooms. The following ambient conditions were measured at a specific facility and are typical for the functions listed. Actual values for a particular room may vary depending upon the lighting systems utilized.

For a particular room, the position of a display device in relation to the room lighting must be considered along with the reflective properties of the device being installed, i.e., anti-glare or anti-reflective coatings or none.

Table 1: Typical Ambient Lighting (In Lux)

Operating rooms	300 - 400
Emergency medicine	150 - 300
Clinical viewing areas	200 - 250
Staff offices	50 -180
Diagnostic reading rooms (CT/MR/NM)	15 - 60
Diagnostic reading rooms (x-ray)	2 - 10

Ambient Light Reflection

Reflected ambient light comes in two flavors for consideration in the hospital/PACS environment. The proper terminology is specular and diffuse reflectance. In each case the light energy is striking the faceplate of the CRT and interacting with the glass, the phosphor structure and any optical coatings to cause reflected artifacts. Good image quality is obtained by maintaining the intensity of light striking the display surface at a low level — the obvious solution isn't always the most realistic to implement in a hospital — so how and what can be done with the two flavors of ambient light?

Specular reflections produce mirrored images of objects in the room to appear on the display surface. They are particularly noticeable in dark areas of the image where their structured appearance produces confusing features which can mask information in the image. The specular reflectance characteristics of a particular device is characterized by a coefficient, Rs ,which is the ratio of the luminance of the virtual appearance of a reflected object to the actual luminance of the object.

Diffuse reflections produce a relatively uniform luminance to the entire display surface. In dark regions of the image, this ambient luminance can be larger than the image brightness if the illuminance of the surface is too great. In these regions, the contrast associated with small detail will be markedly reduced. The effect is similar to placing a semi-transparent veil over the surface of the display. The diffuse reflectance characteristics of a particular device is characterized by a coefficient, Rd , which relates the luminance observed on the surface when the device is turned off to the illuminance of the surface under particular lighting conditions. This coefficient has units of luminance per illuminance typically expressed as cd/m2 per Lux.

Table 2 - Maximum Room Lighting (Specular Refl. Limit)

L_{min}	C_t	.002	.004	.008	.020	.040 = R_s	
20	.007	244	122	61	24	12	
10	.008	140	70	35	14	7	Max
4	.012	84	42	21	8	4	= Room
2	.017	59	30	15	6	3	Lux
1	.024	42	21	10	4	2	

L_{min} in cd/m^2

The ambient illumination (LUX) which maintains specular reflections of white and black objects below the visual contrast threshold (Ct) is tabulated for specific Rs and Lmin values.

Guidelines for room lighting

With a knowledge of the specular and diffuse reflectance characteristics of a particular device, a limit of the acceptable amount of ambient light may be specified. Separate criteria need to be considered for the maximum ambient lighting that will produce acceptable contrast loss for diffuse reflections and acceptable artifacts from specular reflection. Henry Ford Health System has developed a set of tables to establish the maximum amount of ambient lighting (Lux) that should be allowed for a particular display system which are presented in the following as a general guideline for other organizations.

Direct reflections from any lighting fixtures should always be eliminated by appropriate placement of the monitor. However, it is still necessary to reduce specular reflections from any white/black objects such as a dark tie on a white shirt. The luminance of the white portion of such an object depends on the illumination from ambient lights. Reducing the ambient illumination can reduce the contrast between the white and black regions. An appropriate criteria is that the contrast of such objects be below the visual contrast threshold which varies with image brightness. Referring to table 2, if a display with Rs = .004 is set up with the minimum brightness, Lmin, equal to 2 cd/m2, then the ambient room lighting should produce an illuminance on the screen no greater than 30 Lux. If the illuminance needs to be reduced, either the position of the monitor in the room or the amount of room lighting should be changed.

The diffuse reflection of light from a display surface adds an unstructured constant luminance to the image which reduces the contrast in dark regions of the image. The relative change in contrast produced by ambient illumination

Table 3: Maximum Room Lighting (Diffuse Refl. Limit)

L_{min}	.005	.010	.020	.040	.060 = R_d nit/Lux	
20	1000	500	250	125	83	
10	500	250	125	62	42	MAX
4	200	100	50	25	17	= ROOM
2	100	50	25	12	8	Lux
1	50	25	12	6	4	

L_{min} in cd/m^2

The ambient illumination (Lux) which reduces image contrast in dark regions by 20% is tabulated for specific Rd and Lmin values

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should not be less than about .8 to preserve good contrast transfer. The following tabulates the maximum ambient lighting limit or a display with a specific diffuse reflection coefficient and minimum luminance setting. Referring to table 3, if a display with Rd = .02 is set up with the minimum brightness, Lmin, equal to 2 cd/m2, then the ambient room lighting should produce an illuminance on the screen no greater than 25 Lux. If this is the same monitor as above, the diffuse reflection limitation of 25 Lux is about the same as the specular reflection limit of 30 Lux. Again, if the illuminance needs to be reduced, either the position of the monitor in the room or the amount of room lighting should be changed.

Diffuse reflectance is the stealthier of the two reflection problems since it effects the entire screen somewhat uniformly, thereby not calling attention to itself like the sharp contrast edge of a lamp or white lab coat walking by. Lost information from diffuse reflectance leaves no warning flags behind and should therefore be treated with the same due diligence as specifying the display performance.

Planning for Your PACS environment

The diagnostic reading room has by far the most controlled lighting and affords the maximum dynamic range for the display and the human visual system (HVS) combination. In these rooms, a minimum luminance of about 1 cd/m2 (.3 fL) can often be used without introducing degradation from reflections. To maintain the image brightness within the eyes sensory range (after adaptation) the maximum luminance should be about 250 times the minimum luminance. A higher peak luminance would require the eye to adapt upward, losing the lower tones. Thus, a monitor with a peak luminance of 250 cd/m2 (75 fL) can be used for diagnostic reads in a controlled environment.

The same display placed in an emergency trauma center would degrade a large portion of a diagnostic displays information since both specular and diffuse reflections would be well above the luminance of the lower gray tones. With the high ambient lighting in such rooms and the same criteria as above, displays with a minimum luminance of about 10 cd/m2 (3 fL) and a maximum luminance of about 2500 cd/m2 (730 fL) are required. Softcopy devices with this brightness are not available. It is particularly important to position devices in these rooms such that the illuminance of the surface is shielded from the high light levels found in the normal working areas.

Since the available solution is not to be found in a 2500 cd/m2 display, reducing the influence of the bright room is as good as finding more luminance range in the display. The best vehicle for this is an Anti-Reflective (AR) coating. AR coatings are multi-layers of light absorbing material that can be thought of as a light sponge. High quality AR coatings reflect less than .3% of the incident light over the majority of the visible spectrum. Since AR coatings are applied to glass substrates which are in turn bonded to the CRT faceplate, tinting of the glass is also possible. This property aids in contrast enhancement since any incident light not captured by the AR will be attenuated twice — going in and coming out of the glass structure. Two levels of tint are standard at 90 and 60 percent transmittance. Here the tradeoffs with total luminance and MTF need to be considered in the selection process for softcopy in high ambient conditions. Whatever your ambient conditions, plan for them with knowledge.